Life Sciences Beyond ISS

NAC HEOMD Research Subcommittee
7 March 2016

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Life Sciences Lead
Office of the Chief Scientist

Outline

- Life Sciences Capability (Leadership)
- Stepping Stones on the Journey to Mars
- Future Possibilities

The Perennial Challenges

- NASA's aspirations exceed its budgetary resources
- NASA's aspirations change faster than it can complete missions
  - External forces
    - Congress
    - National Academies
    - Office of Management and Budget
    - Office of Science and Technology Polidy
  - Technological advances
  - Internal forces
- Coordinating across 150+ programs and 10 field centers

Towards a Solution: Capability Leadership

- Create a set of advisers to the Agency's top managers and management councils
  - Support annual budget formulation cycle
  - Support ad hoc requests

- Responsibilities
  - Ensure proper alignment across Mission Directorates and Field Centers
  - Guide prioritization of tasks
  - Advise on capability sizing and strategic hiring
  - Assess opportunities for investments and divestments
  - Solicit innovative ideas from outside the capability area

- Form a team to support each adviser
  - Members from programs and field centers
  - Liaisons to other teams and other NASA organizations (e.g., OCHMO)

Capability Leadership Areas

Engineering

Avionics
Flight Mechanics
Human Factors
Life Support
Propulsion
(plus 14 more)

Entry, Descent & Landing
In Situ Resource Utilization
(plus 2 more)

Research

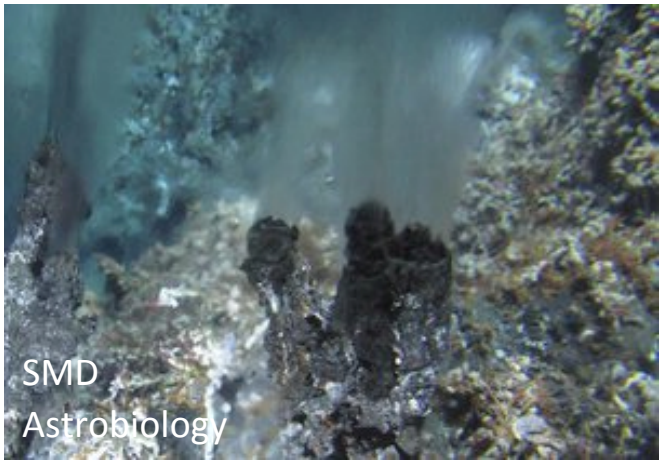
Earth Science
Planetary
Heliophysics
Astrophysics

Life Science

Services

Mission Ops
Aircraft Ops
Environment Testing

Programmatic Scope



Life Sciences Research Capability Team Membership

1. Capability Leader

2. Astrobiology
3. Human Research Program
4. Planetary Protection
5. Space Biology

6. Ames Research Center
7. Glenn Research Center
8. Goddard Space Flight Center
9. Jet Propulsion Laboratory
10. Johnson Space Center
11. Kennedy Space Center
12. Langley Research Center

Excludes medical operations and human systems integration

LSRCT Goals

- Promote cross-agency awareness and coordination of NASA's Life Science capabilities and needs

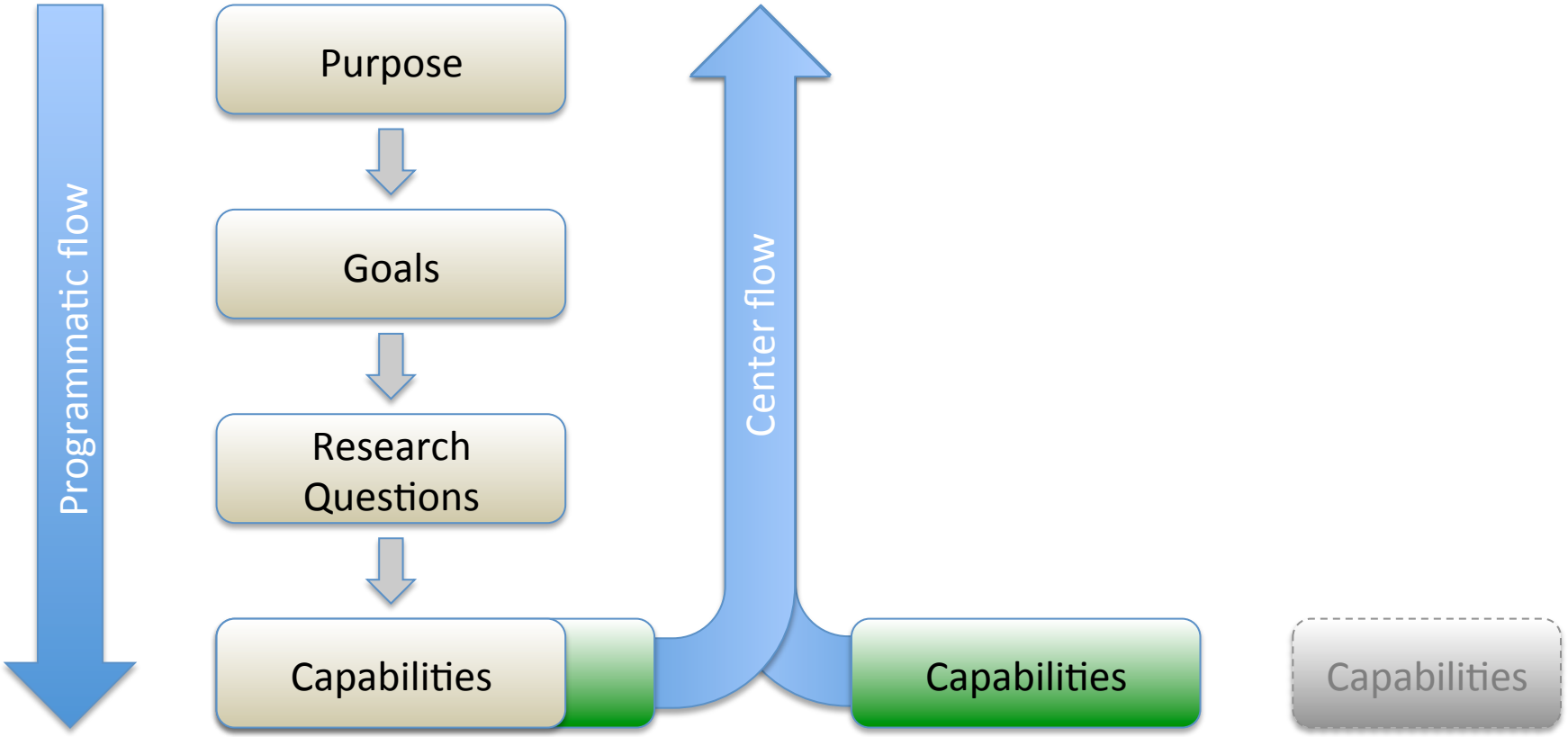
- Provide recommendations and status concerning NASA's Life Science Capability to
  - Organizations participating in the LSRCT
  - Senior management
    - Chief Scientist
    - Chief Health and Medical Officer
    - Agency Program Management Council
    - Mission Support Council
    - Other senior NASA management

Timescale

- Horizon for Capability analysis
  - 30 year career of civil servant

  - Mars surface exploration by humans

Purpose-driven Framework



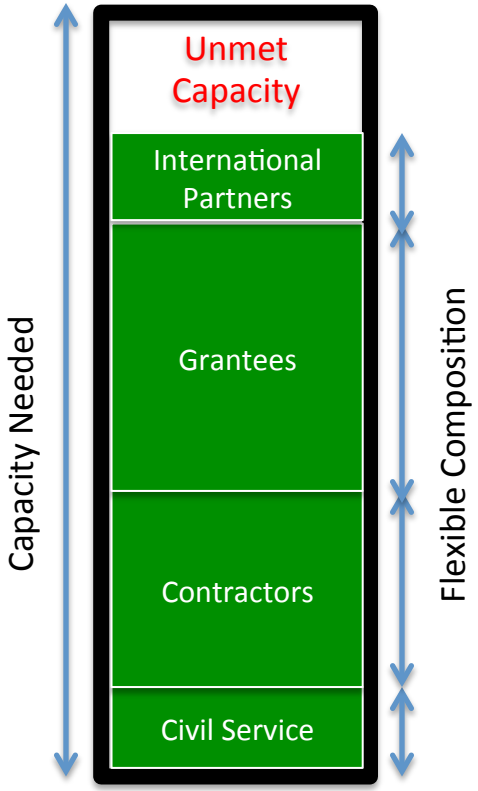
Tier 1 Questions

1. Does NASA have the proper Life Sciences Research capability to efficiently execute current and future missions?

2. If not, what corrective measures are recommended?

Tier 2 Questions

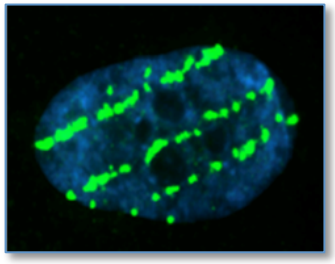
- Present
  - What Capabilities do we have now?
  - What Capabilities do we need now?
  - Does current technical capacity match current demand?
  - How much overlap/resiliency/redundancy exists now across the centers?
- Future
  - What Capabilities do we need for future missions?
  - How sensitive are Capability needs to choice of roadmap, mission architecture, etc.?
  - How does projected capacity match projected demand?
  - How much overlap/resiliency/redundancy is planned across the centers?
- Collaborations
  - What collaborations across field centers or programs within each Capability would be beneficial?
  - What collaborations across field centers or programs and between Capabilities would be beneficial?
  - What collaborations with external organizations would be beneficial?



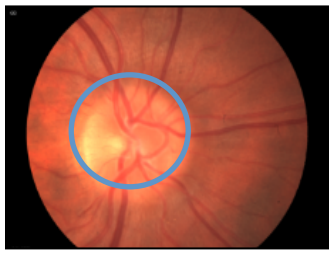
Immunology Technical Capacity (NOTIONAL)

Example Workforce Considerations

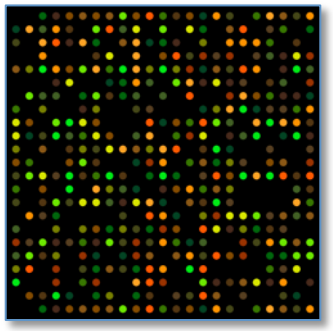
- Example 1: Radiation Biology
  - The interaction of SPE and GCR with human biology is unique to space agencies
  - Radiation biology will be important as humans explore beyond LEO
  - Needs junior and senior level civil servants
    - Alternate views
    - Succession plan
    - Expertise does not exist outside of NASA



- Example 2: Visual Impairment / Intracranial Pressure (VIIP)
  - Phenomenon observed with long duration crew
  - Important in LEO and beyond
  - NASA and outside community predict prevention or treatment will be available in 5-10 years
  - Utilize IPAs, contractors, and grantees rather than hire civil servants

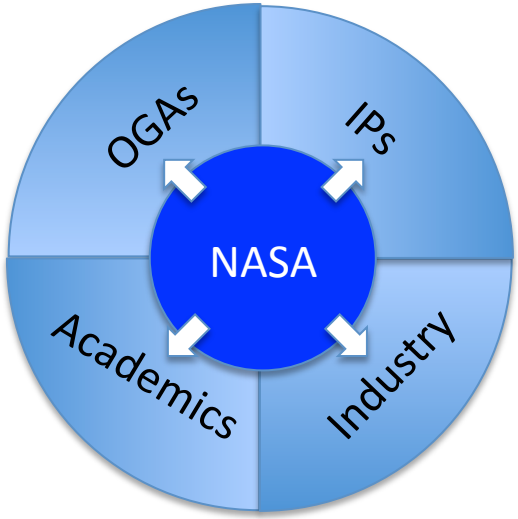


- Example 3: Systems Biology
  - Important approach for understanding organism's response to space flight
  - New techniques available every few months
  - Field moving too fast for NASA to commit to specific expertise
  - Utilize IPAs, contractors, and grantees rather than hire civil servants



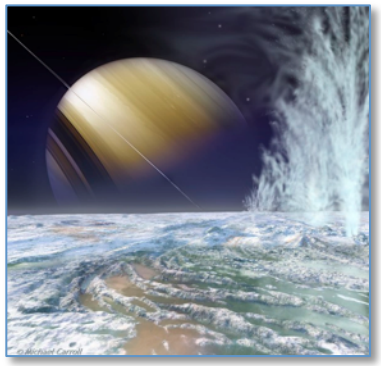
LSRCT Schedule

- Year One Emphasis: NASA
  - Assess the match between our needs and our capability
  - Identify truly valuable collaborations within the Agency
- Year Two Emphasis: Coordinate with outside organizations to increase our capability
  - Federal agencies (e.g., NIH, NSF, DoD, CDC)
  - International Partners
  - Industry
  - Academics
- Continuous: Facilitate strategic hiring decisions with an agency wide strategic framework



Capability Leadership Summary

- NASA has adopted the Capability Leadership Model to better employ resources and respond to changes in direction
- The Life Sciences Research Capability is part of the CLM
  - Includes Human Research Program, Space Biology, Astrobiology and Planetary Protection
  - Excludes, but liaises to, medical operations and human systems integration
- The Life Sciences Research Capability provides a new mechanism for fostering coordination and collaboration across NASA

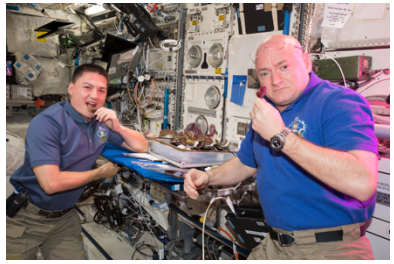


Outline

- ✓ Life Sciences Capability (Leadership)
- ➢ Stepping Stones on the Journey to Mars
- Future Possibilities

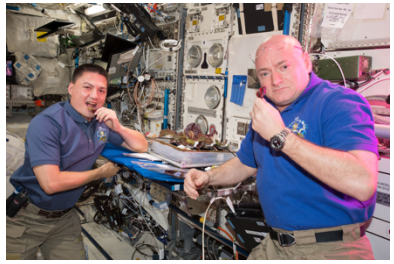
Stepping Stone Concepts

- From a human exploration perspective, every mission short of a landing on Mars is an analog for the 'horizon destination'
- The research path for enabling exploration progresses
  - from low fidelity (fast, cheap, high N)
  - to high fidelity (slow, expensive, low N) analogs
- Fidelity has many dimensions
- The research path is a sequence of stepping stones
- Choose the largest steps possible

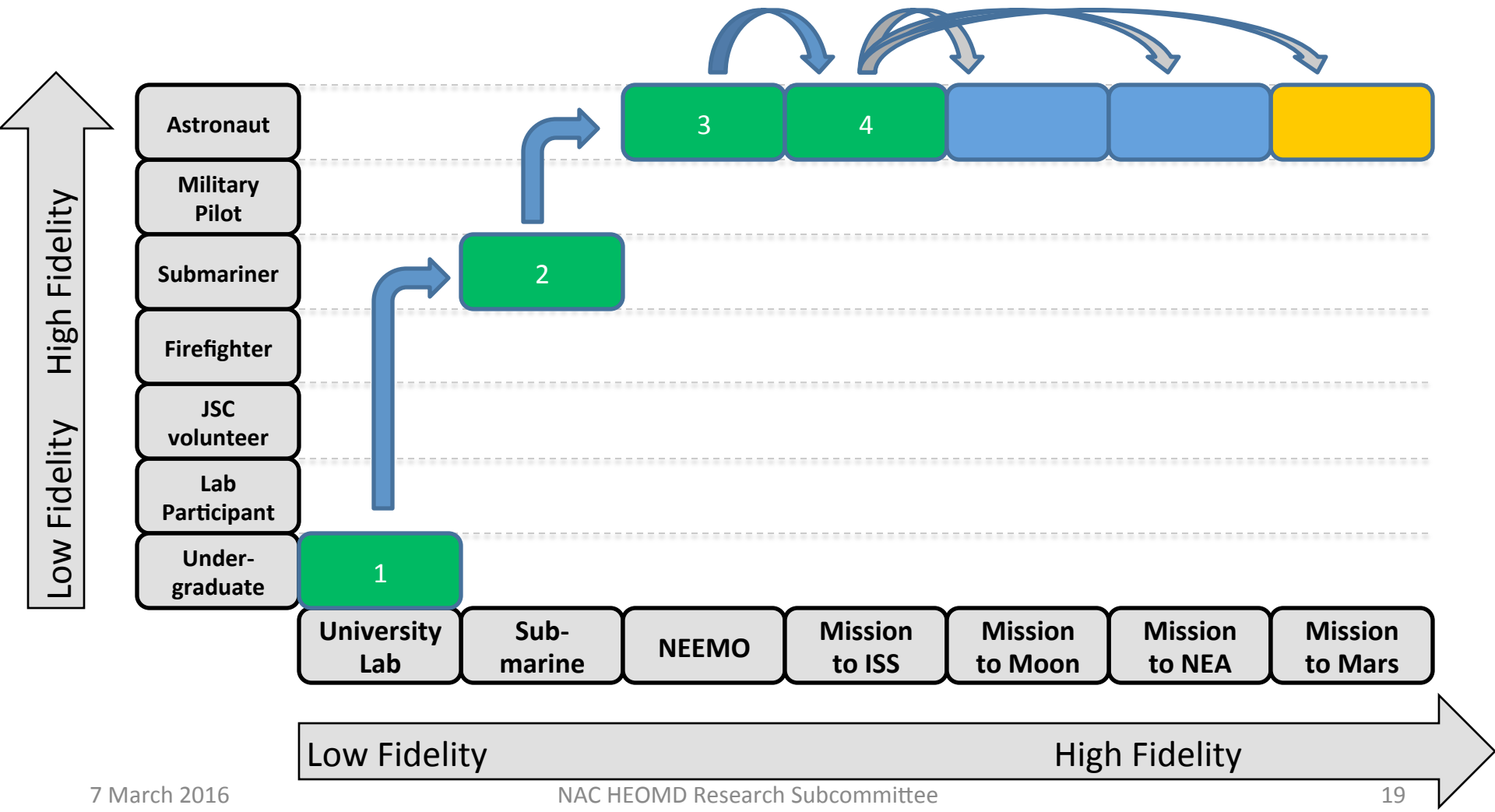


Fidelity has many dimensions

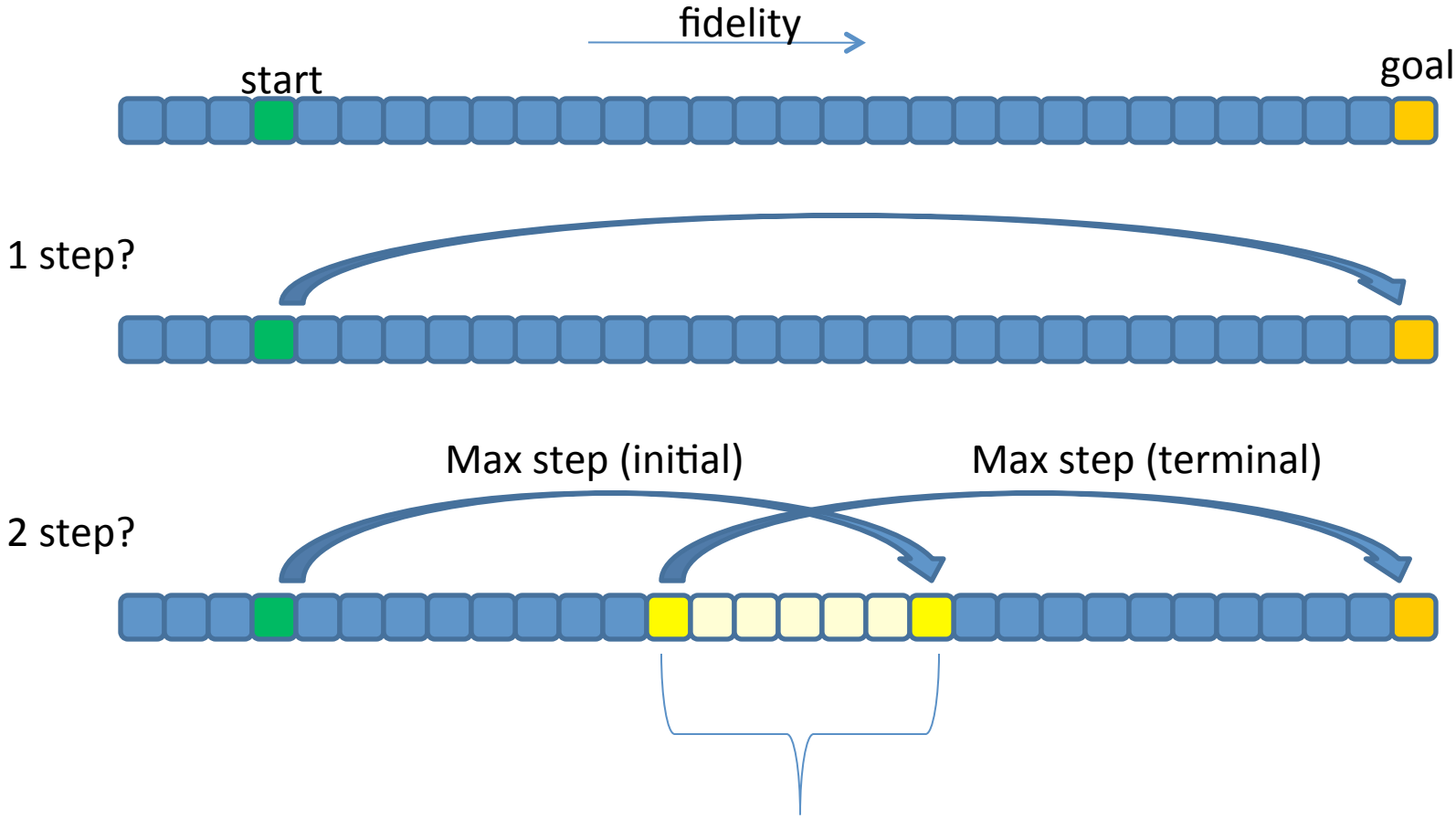
- Examples from Behavioral Health and Performance:
  - Subject
  - G levels and transitions between
    - 0, 1/6, 3/8, 1, 4, 8
  - Radiation
  - Duration
  - Confinement
  - Isolation
  - Activity level
  - Type of work
  - Mission control
  - Telemedicine capability
  - Autonomy



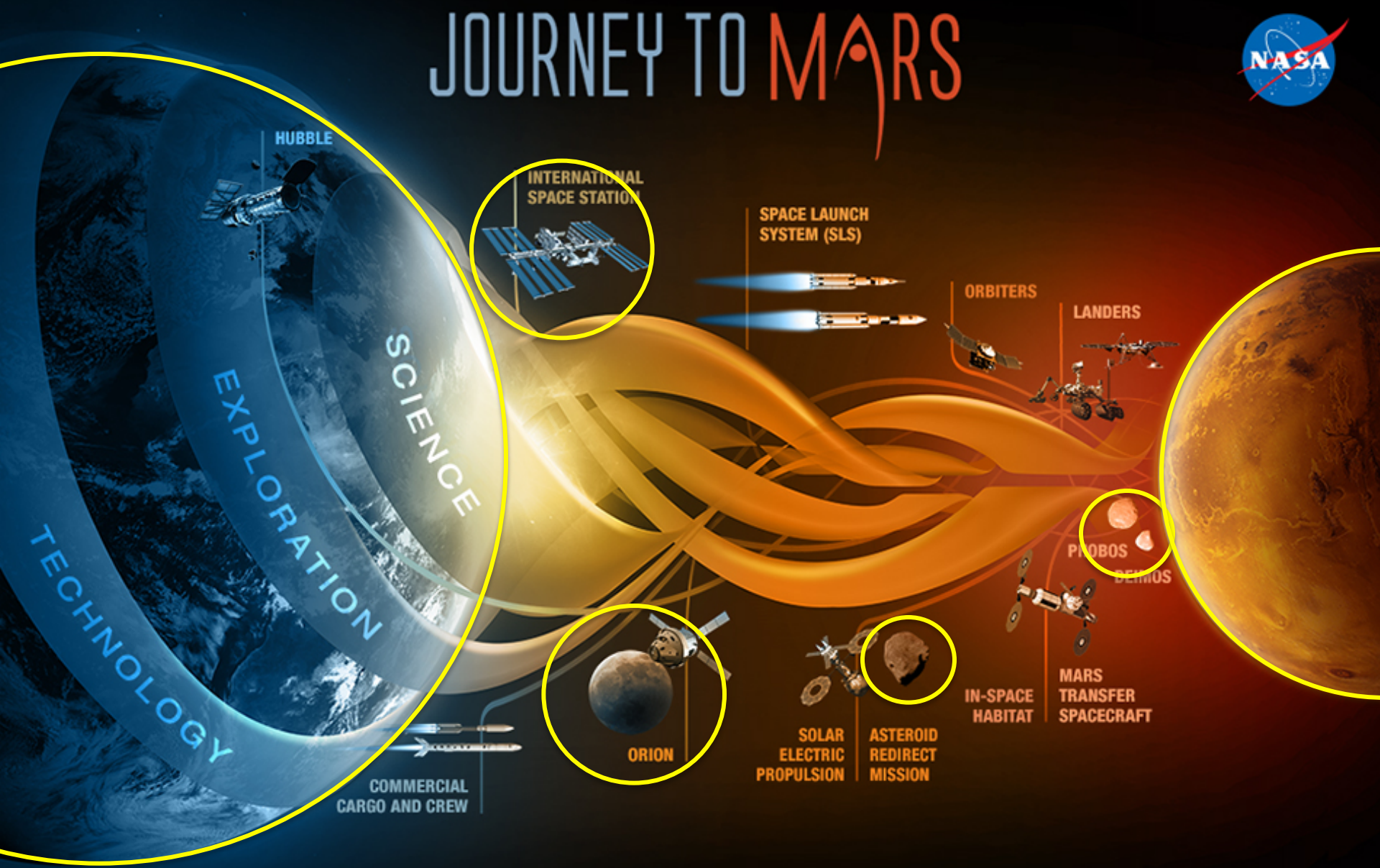
Team Dimensional Training



Choosing the steps judiciously

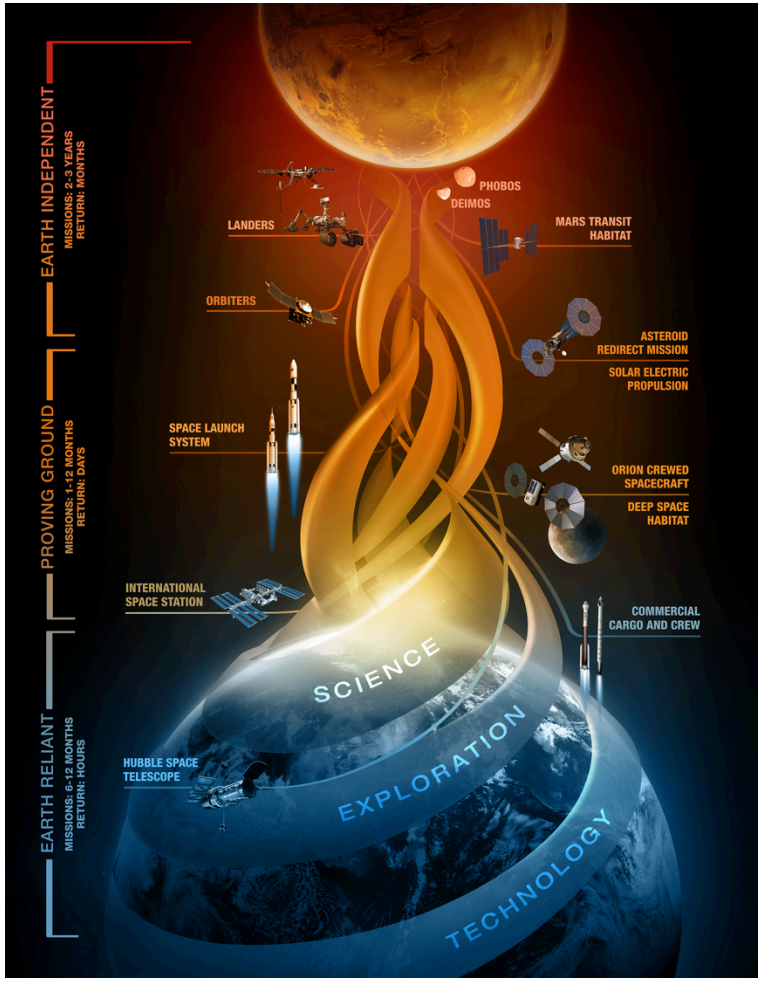


Acceptable intermediate stepping stones for taking two steps from start to goal


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
ORION
COMMERCIAL CARGO AND CREW
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT

Stepping Stone Summary

- From a human exploration perspective, every mission short of a landing on Mars is an analog for the 'horizon destination'
- Fidelity has many dimensions
  - Some terrestrial analogs are better than spaceflight in some dimensions
  - Spaceflight mission vary in their fidelity across the dimensions
- There are many venues for life science research in support of exploration



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Two Types of Research

1. Research that **enables** space exploration:

   scientific research in the life and physical sciences that is needed to develop advanced exploration technologies and processes, particularly those that are profoundly affected by operation in a space environment.

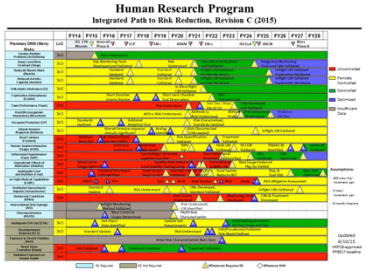
2. Research **enabled by** access to space:

   scientific research in the life and physical sciences that takes advantage of unique aspects of the space environment to significantly advance fundamental scientific understanding.

Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era (2011) National Academy of Science

Enabling

Focused on Exploration

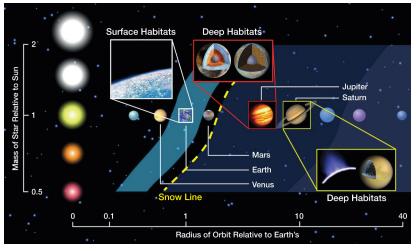


Human Research Program

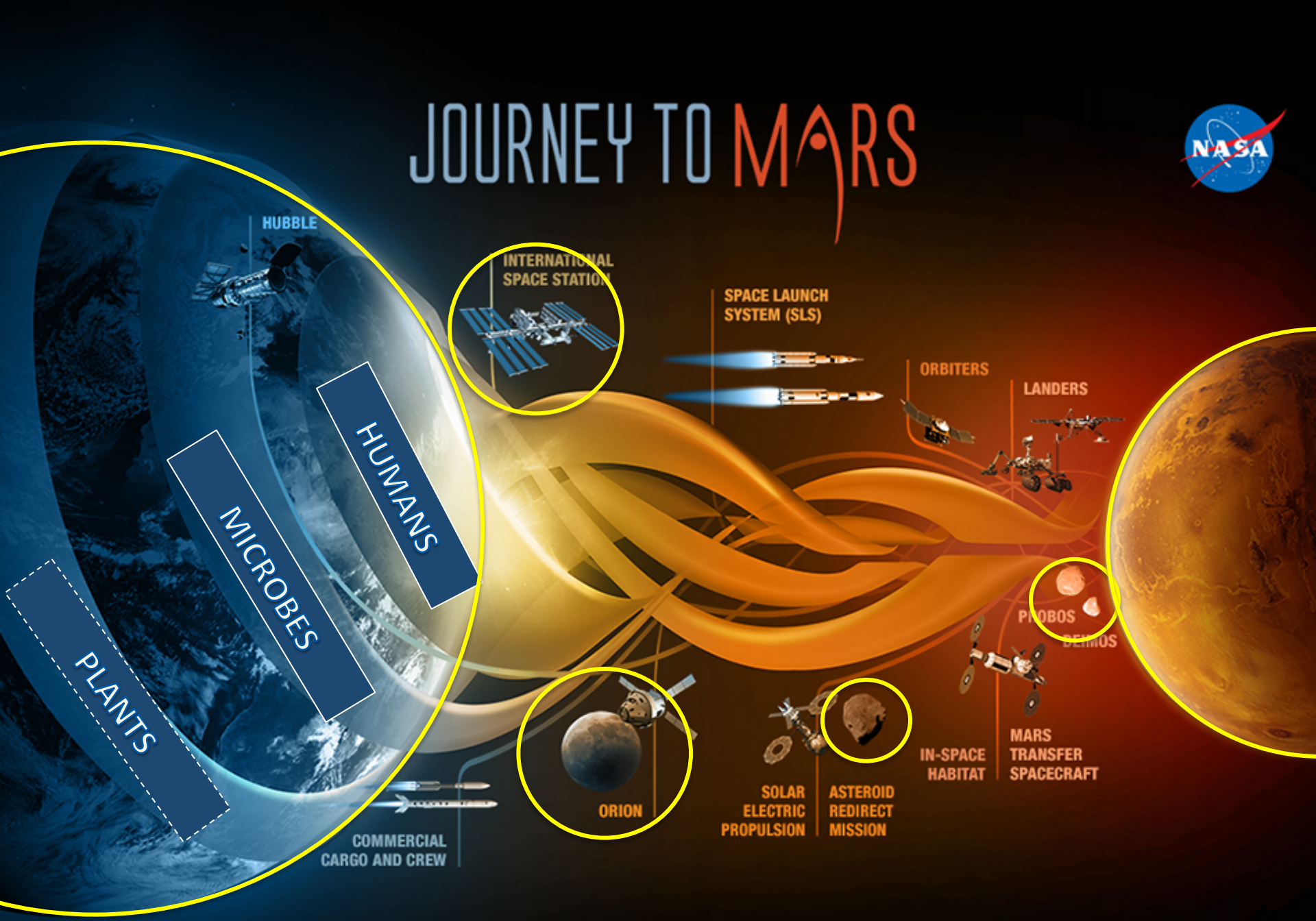
Planetary Protection

Includes Exploration

Space Biology



Astrobiology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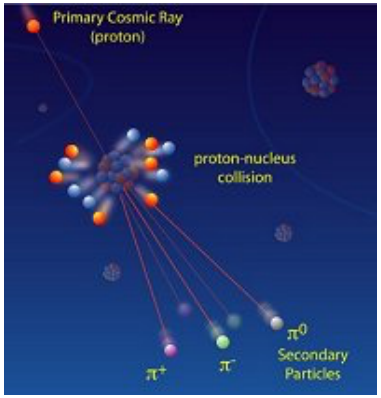
Enabled By (Stimulus)

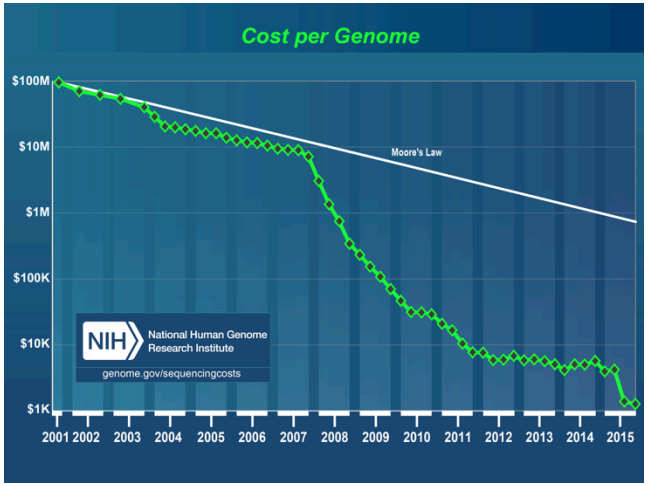
Spaceflight stresses living organisms in many ways, some unique

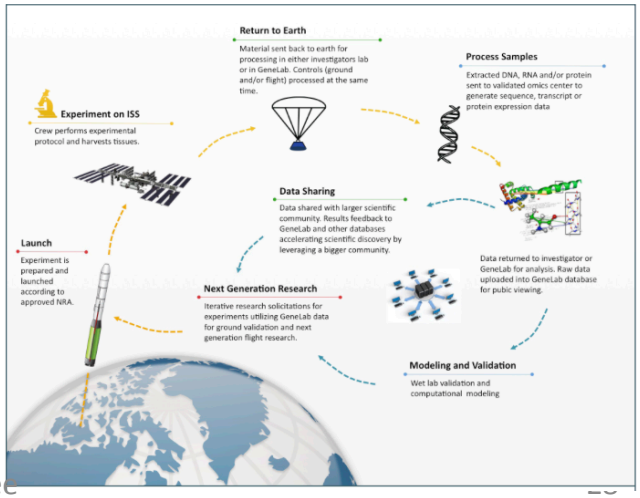
- See earlier slide on dimensions of fidelity for analogs
- ISS examples
  - Weightlessness
    - No buoyancy driven convection
      - Marangoni convection remains
    - No sedimentation
      - Weightless human on treadmill
    - No hydrostatic pressure
      - Fluid shifts in human
  - Hyperacceleration during launch and landing
  - Radiation
  - High pCO_2
  - Isolation
  - Confinement
  - Low immunological challenge
    - Food
    - Surfaces



Enabled By (Response)

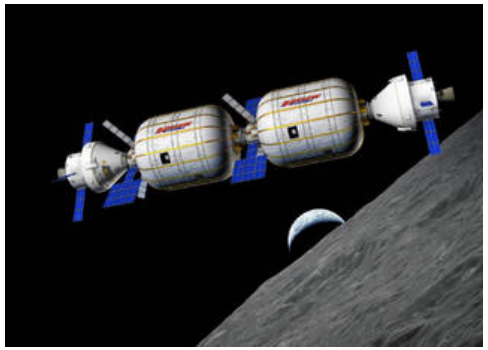
- Advances are occurring rapidly on many fronts
  - Observation
    - Omics technology enables comprehensive molecular characterization of tissues
    - More sophisticated instruments are available on the ground and in flight
  - Theory
    - Computational biology is increasingly able to describe system behavior
  - Manipulation
    - E.g., CRISPR/Cas9
- New types of experiments are now possible
  - E.g., comprehensive rather than targeted observations
- New types of experiments are now enabled by spaceflight
  - What will be next?





Changes in Access to Space

- The ISS is a Golden Age of access to space
  - Regular access
  - Extensive infrastructure
  - Many crew
- Access after ISS
  - LEO: NASA, Commercial?
    - From sub-orbital to CubeSats to new orbital platforms?
  - Beyond LEO: Journey to Mars
    - Less frequent
    - Fewer facilities and crew
- Community input needed (e.g., Decadal Survey)



Conclusion

- NASA now tracks Life Science Research Capability
  - Astrobiology, Human Research Program, Planetary Protection, Space Biology
  - ARC, GRC, GSFC, JPL, JSC, KSC, LaRC
- The Journey to Mars combined with a Stepping Stones approach generates a large range of possible life science research
  - Enabling exploration
  - Enabled by exploration
- Advances in life sciences research measurements, theory, and manipulations create previously unimaginable possibilities for research and application
- Selecting which possibilities to pursue is an exciting challenge needing community input